EMPIR Call 2018 – Health, SI Broader Scope, Normative and Research Potential

Selected Research Topic number: **SRT-s07**
Version: 1.0

Title: Traceable measurement chain for textures on 3D surfaces at below 10 nm uncertainty level

Abstract

The characteristics of surface texture on 3D surfaces are crucial for the engineering of their functional properties (friction, wear, wetting, etc.) with applications in all technical domains.

NMI/DI capabilities to measure and disseminate traceability for surface texture on 3D surfaces would be improved by developing ultra-high precision measuring machines that are traceable to the SI metre with measurement uncertainties below 10 nm, robust reference algorithms for data processing and new 3D transfer standards. This would lead to an enhanced traceable metrology chain that is fully digitalised and thus, consistent and unbroken between any NMI/DI and end-user, giving Europe a world leading measurement infrastructure.

Keywords

3D surface texture, reference material standards, robust data analysis algorithms, traceability, calibration procedures, roughness on curved surfaces, ultra-high precision measurement instruments, uncertainty

Background to the Metrological Challenges

Areal surface texture metrology is crucial for production in the automotive, aerospace, marine, bioengineering, medical, energy, optics and semiconductor industries, as well as in both macro- and micro-mechanical engineering.

There is a need to describe/measure areal surface texture on curved 3D-like surfaces (canonical and freeform surfaces) rather than on flat surfaces. Existing ISO written standards provide tools that allow metrologists to describe such surfaces in a comprehensive way, but the measurement conditions required are challenging. Furthermore, there are no commonly available transfer standards related to these parameters. It is difficult to realise calibration methods and related artefacts at NMIs and DIs for all important parameters needed in industrial production, as it can require the manufacture of thermo-invariant calibration material standards and a new class of ultra-high precision primary instrumentation with 3D capabilities. Additionally, it requires verification of robust algorithms separating form and surface, and implementations of the estimation of areal parameters.

Recent discussions conducted by experts involved in the scientific technical committee “Surfaces” (STC-S) at the International Academy for Production Engineering (CIRP) emphasised the urgent need to develop a reference metrology chain for areal measurements of texture on 3D surfaces with uncertainties below 10 nm at NMI/DI, to serve European industries in all sectors.

Most European NMIs and DIs are equipped with ultra-high precision instruments, which ensure profile (1D) measurements with less than 10 nm uncertainty, but this uncertainty is severely degraded for an assessment of areal (2D) roughness and texture, in particular of the surfaces that are located on 3D objects. To reach an uncertainty below 10 nm by 2025, not only do instruments need be enhanced, but calibration procedures with appropriate material measures and reference algorithms are also urgently needed. The data analysis must guarantee an uncertainty based on the analysis procedure, i.e. the underlying models, the optimisation processes and the numerical implantation algorithms, is at the sub-nanometre level. The only few existing algorithms are almost all dedicated to profile (1D) assessments and they are not certified since reference algorithms do not exist yet. The algorithms for determining the parameters of interest need to be defined with a minimum of ambiguities to facilitate the implementation of the associated program modules into accredited laboratories and industrial software, and to support the harmonisation of surface texture evaluation worldwide. In addition, some rare material standards for profile (1D) measurements exist, while thermo-invariant standards representing areal texture on 3D surfaces do not exist at present. These standards should be investigated and developed by European NMIs to consolidate both traceability and the metrology chain, ensuring accurate transfer to accredited laboratories and industries.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The JRP shall focus on the development of a metrology chain traceable to the SI metre definition for areal surface texture with nanometre level uncertainty.

The specific objectives are

1. To improve the capabilities of NMIs and DIs to measure areal surface texture parameters on 3D artefacts using tactile and/or optical probing systems integrated in ultra-high precision measuring machines traceable to the SI metre definition. Measurement uncertainties should be reduced to satisfy the requirements for the calibration chain. The target uncertainty level for the selected parameters shall be below 10 nm.
2. To develop robust reference algorithms (software) harmonised across all NMIs and DIs for separating form and texture and for the consistent determination of areal texture parameters. To verify that the algorithms lead to ultra-precise analysis of measured data in accordance with the definitions of ISO GPS standards (Geometric Product Specification). To develop methods for the estimation of uncertainties of selected surface parameters. To generate data sets as softgauges to ensure the validation of existing software by comparison campaigns.
3. To define and manufacture suitable validated reference material standards representing areal textures on shaped 3D artefacts, for most relevant parameters. To define thermo-invariant materials for the standards to minimise the effect of the environmental temperature variations. Typical size of shaped texture material standards should be in the range between 5 mm and 200 mm. Those reference standards will be calibrated using ultra-high precision measuring machines and the calibration traceability should be established.
4. To compare measurement data acquired from different measurement instruments. For that purpose, methods to transform between different surface representations, alignment techniques, data fusion methods and detrending algorithms should be investigated. To investigate and implement validated data analysis procedures necessary for the comparison of measurements performed by different instruments.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (NMIs and DIs), standards developing organisations (e.g. softgauges basic framework ISO, CIRP (STC S)) and end users (medical, defence and safety, energy, aerospace, automotive, photonics industries etc.). To draft guidelines describing measurement procedures of areal texture parameters on 3D artefacts for both stylus and optical instruments. To include instruction of how to carry out texture/roughness measurements on shaped objects in an efficient way with sufficiently small measurement uncertainty. To establish evaluation methods for an estimation of the uncertainty. To perform selected case studies and to make the results available for industrial stakeholders.

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research work, the involvement of the larger community of metrology R&D resources outside Europe is recommended. A strong industry involvement is expected in order to align the project with their needs and guarantee an efficient knowledge transfer into industry.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.8 M€, and has defined an upper limit of 2.1 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 20 % of the total EU Contribution across all selected projects in this TP.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the “end user” community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the engineering, medical, energy, optics, and semiconductor industry sectors.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.